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# Saltmarsh Caterpillars: Temperature Control of Melanism in Larvae

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## ABSTRACT

Saltmarsh caterpillars, *Estigmene acrea*(Drury), reared at temperatures below 30° C are generally dark in color. As rearing temperatures are increased, the caterpillars are lighter, and at a rearing temperature of 33° they are very pale. The low rearing temperature thus results in a dark coloration commonly found in field populations in cool weather that permits maximum utilization of short bursts of radiation, whereas the lighter coloration generally found in field populations during hot weather, resulting from higher rearing temperatures, prevents an overheating of critical physiological systems.

KEYWORDS: *Estigmene acrea*, saltmarsh caterpillar, heat transfer in insects, insect melanism.

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# SALTMARSH CATERpillARS: TEMPERATURE CONTROL OF MELANISM IN LARVAE

By R. E. Fye<sup>1</sup>

## INTRODUCTION

During the studies previously reported by Fye and McAda (4)<sup>2</sup> and Fye and Poole (3), it was noted that saltmarsh caterpillars, *Estigmene acrea* (Drury), (1) were dark when reared in the lower temperature range (about 15° to 25° C) and light colored when reared in the higher temperature range (30° to 33°); (2) in field populations, darker shades were predominant in cool weather and lighter shades in very hot weather; and (3) at higher rearing temperatures, physiological breakdown and poor development appeared. The apparent response of melanism production to temperature should have appreciable impact on the heat transfer between the caterpillars and their environment. The following study was conducted to determine the effects of rearing temperature on the coloration of the saltmarsh caterpillars and to establish the potential change in the developmental rate due to the color differences.

## METHODS AND MATERIALS

Freshly hatched larvae for the tests were taken from the culture material at the Tucson Laboratory, which had been in continuous culture since September 1975 until the tests were conducted in late 1976 and early 1977. During that period, no native stock was introduced into the culture.

About 100 larvae in individual 1-oz cups containing the medium described by Patana (7) were placed in each of the four base temperatures, that is, 20°, 25°, 30°, and 33° C. The larvae were examined daily for molts, and at the end of each of the fourth, fifth, and sixth instar, six to eight larvae were moved to the three other temperature regimens. Approximately 24 h after each molt, at least six insects were examined and the colors recorded. The colors were noted

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<sup>2</sup>Italic numbers in parentheses refer to Literature Cited, p. 5.

for the head capsule, middorsal line, dorsal verrucae, dorsal setae, the laterodorsal stripe, the lateral striping, the coloration in the vicinity of the lateral verrucae, the lateral verrucae, the lateral setae, and the venter. The Munsell Book of Color® (1) was used as the color reference standard, and all criteria for the determination of color, as outlined in the Munsell Book of Color, were met. The one exception was the illumination with a standard microscope light, a modification necessary due to the nature of the study. All color evaluations were made by the author who has no known area of color blindness.

The potential change in heat transfer was studied by placing thermocouples into the abdominal cavity of the larvae through the anal opening. Tests were conducted on five to seven larvae in the fourth, fifth, and sixth instars from the 25° and 33° C rearing regimens. Thus, the dark and light larvae were represented (table 1).<sup>3</sup> The larvae were then placed in a cabinet in which a constant temperature of 26.5° was maintained. The larvae were placed 15 cm from a heat lamp (Westinghouse 250W Reflector Infrared Heat Lamp®). When the larval temperature had stabilized with the cabinet temperature, the heat lamp was switched on, and the temperatures were recorded at a 0.25-min interval with a portable potentiometer. At the end of 3 min, the heat lamp was switched off, and the cooling was recorded in the same manner. Thus, the heat absorption by the larvae was recorded while the ambient temperature around the larvae was held constant.

The effect on development of the improved absorption by the dark larvae, as compared with the light larvae, was tested by placing groups of 25 to 60 larvae reared to the fourth, fifth, and sixth instars at 25° or 33° C, 15 cm below the heat lamp. The larvae were held in open, screen bottom plastic boxes with a petrolatum barrier around the upper rim. Thus, no restraining medium interfered with the radiation input. The heat lamp was placed on a timer to provide a 2-min interval of heat input, followed by a 6-min interval without the heat. Thus, the cabinet maintained the ambient temperature of 26.5°, and the change in heat flux experienced by the larvae was determined by the color and mass. The larvae were color coded with fluorescent pigment dust, and their developmental progress was noted at 12-h intervals. As molts occurred, the number of 12-h periods that the larvae had been in the instar was recorded. Fourth, fifth, and sixth instar larvae were tested to determine the effects of the two colorations on the developmental time.

## RESULTS

The detailed results of the coloration changes due to the rearing temperatures are recorded in table 1. The data are generally self-explanatory and indicate that the darker larvae reared at the lower temperatures, when placed in the higher temperatures, tend to become lighter. If the change is made in the fourth instar, the lighter coloration is highly apparent by the end of the total larval period. The transformation to the lighter colors is less if the move to the higher temperatures is made in the fifth or sixth instar. If the larvae were moved immediately after the molt, the change within that particular instar was more apparent than if there were some delay. When the larvae reared at the

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<sup>3</sup>Table 1 begins on p. 8.

higher temperatures were placed in the lower temperatures, the reverse process occurred with the darker larvae in the final instars coming from those moved to the lower temperatures in the fourth instar. Generally, the color changes in the first three instars were not extensive, and the major color changes occurred in the later instars.

In general, the darker colors were the result of an extensive increase in the black pigment that masked the red and red-purple pigments that were more obvious in the lighter insects. Even in the blackest-grayest forms reared at low temperatures, occasional tinges of red or red-purple pigments were apparent. The increasing darkness was most obvious in the dorsal verrucae and the setae initiating in these verrucae. In the mottled dorsal lateral stripe, the darker pigment in the mottle also overrode the lighter pigment to provide the generally darker appearance. In the lateral areas of the larvae, the striping was generally reduced, and the pigmentation in the vicinity of the verrucae was masked by the melanistic pigments. In the lighter specimens from the higher temperature regimens, the process was reversed with the darker pigments disappearing. None of the melanistic pigments were noted in the fecal material of the larvae, but the fecal pellets were frequently coated with the light red-purple pigments.

The results of the heat flux experiments are presented in figure 1. The dark larvae in all three instars warmed more rapidly than the light larvae. The tendency is not as evident in the fourth instar with their smaller mass (about 0.09 g), as it is in the larger fifth (about 0.50 g), and sixth instars (about 1.20 g) and the increasing volumes, about 60, 300, and 960 mm<sup>3</sup>, respectively, for the three instars. The increased volume and mass of the larvae are also reflected in the flattening of the heating and cooling curves.

The developmental periods of larvae held beneath heat lamps for 2 min of each 8-min period are presented in table 2. The developmental period for the dark larvae in all three instars is shorter than that of the light larvae. The differences are significant at the .01 probability level, as indicated by the T test. Thus, the melanism differences affected by the rearing temperatures had significant impact upon the developmental time in the subsequent instars.

TABLE 2.--*Developmental time for light and dark salt marsh caterpillar larvae*

Instar	Developmental time in instar (No. of 12-h periods $\pm$ S.E.)	
	Light <sup>1</sup>	Dark <sup>1</sup>
4th	6.1 $\pm$ 0.1	5.4 $\pm$ 0.1
5th	7.2 $\pm$ 0.3	6.5 $\pm$ 0.2
6th	9.0 $\pm$ 0.2	9.1 $\pm$ 0.1

<sup>1</sup>Light reared to the instar indicated in column 1 at 33° C. Dark reared to the instar indicated in column 1 at 25°.

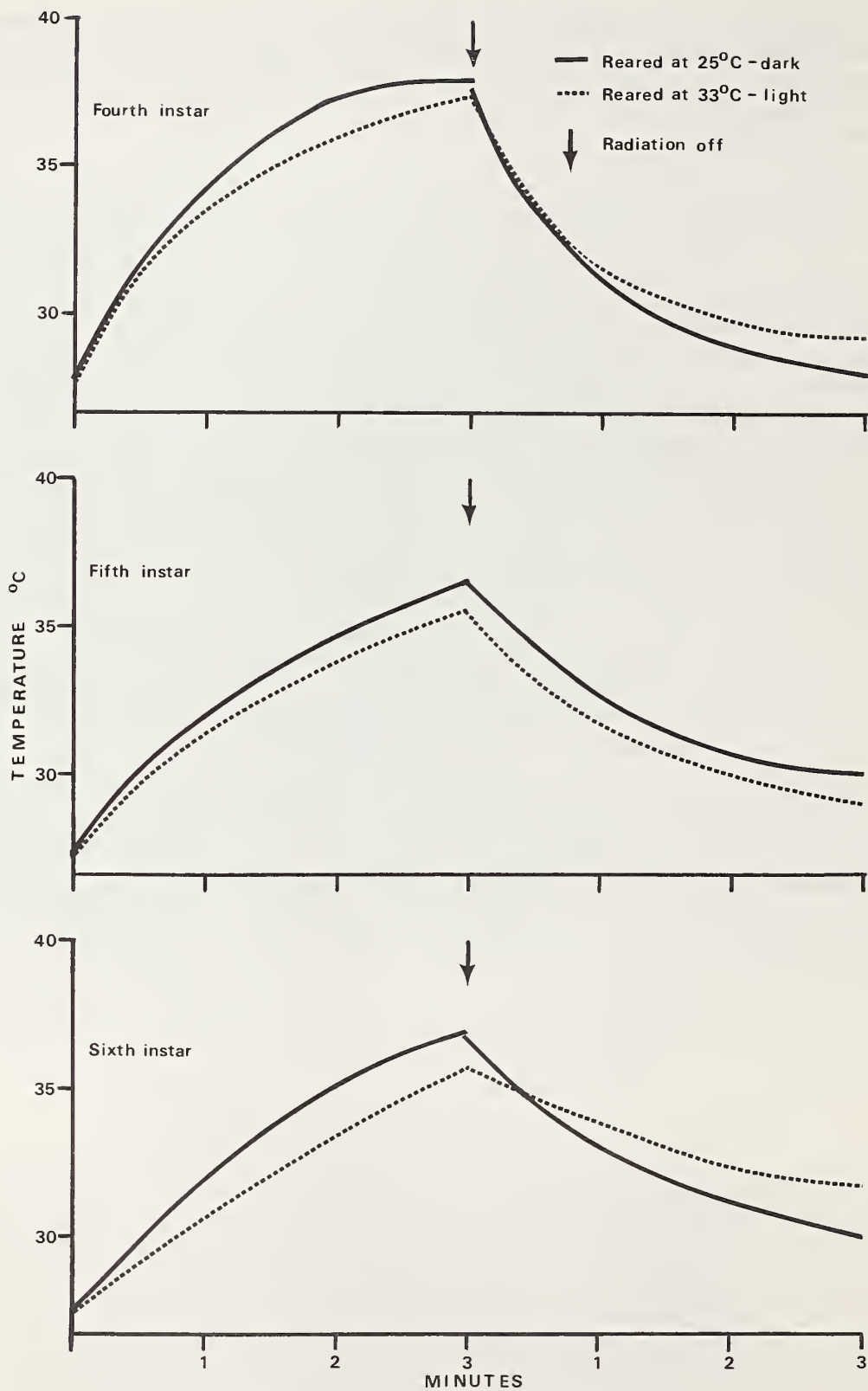


Figure 1.--Representative heating and cooling curves of saltmarsh caterpillars subjected to heat lamp radiation for 3 min.

## DISCUSSION

Discussions of the various aspects of melanism are voluminous, and the effects of coloration on physiology and behavior, particularly of desert animals, are frequently noted (for example, 6, 9). Casey (2) noted the basking of *Hyles lineata* (F.) to elevate their body temperatures, and the orientation of the caterpillars to effect the proper temperature relationship with the environment. This study indicates that the saltmarsh caterpillar has a physiological response in regard to the production or nonproduction of the melanistic pigments that permits the best physiological use of the available radiation. The dark colors resulting from low temperatures would permit the larvae brief periods of development from sporadic radiation input. On the other hand, the light colors resulting from high developmental temperatures would reduce the adverse effects of periods of high radiation input. The phenomenon is not unique to the saltmarsh caterpillar, and we have observed it in the rearing of pink bollworms, *Pectinophora gossypiella* (Saunders), *Sinea confusa* Caudell, *Zelus renardii* Kolenati, *Nabis alternatus* Parshley, and *N. americanoferus* Carayon. Kelton (5) noted that several species of *Lygus* have darker coloration during the winter months. Westigard and Zwick (10) have noted that pear psylla, *Psylla pyricola* Forester, in the adult overwintering form, are larger and darker than summer adults.

Thus, the adaptation of the physiological system to produce melanism appears to have evolved to utilize short term radiation through changes in pigmentation.

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Table 1 begins on page 8.

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TABLE 1.--Coloration of saltmarsh caterpillars, *Estigmene*

Base or test temperature	Larval instar	Head capsule	Dorsum			
			Middorsal line	Dorsal verruca (8) <sup>2</sup>	Dorsal setae	Laterodorsal stripe
20° C	1	5Y or 10YR 2.5/1, N1.75	5Y 9/1. N9.25	2.5Y 4-5/5-6	( <sup>6</sup> )	5 or 10YR 7/6, 5YR 7/10
	2	5Y or 10YR 2.5/1	N9.25, 5Y 9/1	5Y 2.5/1	5 or 10YR 2.5/1	5YR 4/4, 7.5YR 4/6
	3	5 or 10YR 2.5/1	N9.25, 5Y 9/1	N1.75	5YR 2.5/1	5YR 3/2 or 4/4
	4	N1.75	5Y 9/1, N9.25	N1.75	10YR 2.5/1	5R 3+7/1
	5	N1.75	Vague, 5Y 9/1	N1.75	N1.75 5YR 2.5/1	5R or 10RP 2.5 + 5/1
	6	N1.75	None	N1.75	N1.75	N1.75 + 4.25
	7	N1.75	None	N1.75	N1.75	N1.75 + 5.25
	25°	4	N1.75	N9.25, 5Y 9/1	10YR 2.5/1	5R 2.5-3 + 5-8/1
	5	N1.75	Vague, 5 or 10Y 9/1	N1.75	5 or 10YR 2.5/1	10RP 2.5 + 4-7/1
	6	N1.75	None, 5Y 9/1	N1.75	10RP or 10YR 2.5/1	10RP 2.5 + 4-7/1
	7	N1.75	None, 5Y 9/2	N1.75	10RP 2.5/1	10RP 2.5 + 6/1
	30°	4	N1.75 10YR 2.5/1	N9.25 5Y 9/1	10YR 2.5/1	5 or 10R 2.5 + 7/1
	5	N1.75 5YR 2.5/1	5 or 10Y 9/1-2	5 or 10YR 2.5/1	5 or 10YR 2.5/1	10RP or 5R 2.5 + 6/1
	6	10YR 2.5/1	Vague or 5Y 9/1	10YR 2.5 or 9/1	10YR or 5R 2.5/1	10RP or 5R 2.5 + 6/1
	7	10YR 2.5/1	None	5Y 2.5/1 Light tips	10RP 2.5/1	10RP 2.5 + 6/1
	33°	4	N1.75	N9.25	10YR 2.5/1	10RP 2.5 + 5-7/1
	5	10YR 2.5/1 + 6/6	10Y 9/1	5Y 8/4	10YR 2.5/1	10RP or 5R 2.5 + 5-8/1
	6	10YR 2.5/1 + 7/6	5Y 9/2	10YR 9/1	10YR 9/1	10RP or 5R 2.5 + 8-9/1
	7	10YR 5/6	5Y 9/1	5Y 9/1	5R or 10RP 9/1	10RP 3 + 9/1
	25°	5	N1.75	Vague, 5Y 9/1	N1.75	5 or 10YR 2.5/1
	6	N1.75	Very vague	N1.75	10RP 2.5/1	10RP 2.5 + 5/1
	7	N1.75	Very vague	N1.75	N1.75	N1.75 + 4.5
	30°	5	N1.75	Vague 5Y 9/1	N1.75	5 or 10YR 2.5/1, N1.75
	6	N1.75 or 10YR 2.5/1	Vague	N1.75	10RP 2.5/1	10RP or 5R 2.5 + 6/1
	7	5YR 2.5/1	Vague	N3	5R 2.5/1	5R 2.5 + 5/1
	33°	5	N1.75	Vague	10YR 2.5/1	10RP 2.5 + 4-6/1
	6	10YR 2.5/1	5Y 9/2	10YR 9/2	10YR or RP 9/1	10RP 2.5-4/5-8
	7	10YR 2.5 + 6/1	5Y 9/2	10YR 9/2	10RP 9/1	10RP 2.5-4/8-9
	25°	6	N1.75	None	N1.75 10YR 2.5-1	N1.75 + 3.75-5, 10RP 2.5 + 5/1
	7	N1.75	None	N1.75 or 10YR 9/2	10RP 3/1	10RP 2.5 + 7/1
	30°	6	N1.75	None	N1.75 or 10RP 2.5/1	10RP 2.5 + 6/1 N1.75 + 5
	7	N1.75	None	N1.75	10RP 2.5/1	10RP 2.5 + 6/1
	33°	6	N1.75	None	N1.75 10RP 2.5-1	N1.75 + 4-5
	7	10YR 2.5/1	Sporadic	10YR 9/2	10RP 5 + 9/1	10RP or 5R 3 + 7/1
25°	1	5Y or 10YR 2.5/1	5Y 9/1	5Y 4/2-4	( <sup>6</sup> )	5 or 10YR 6/6
	2	10YR 2.5/1	5Y 9/1 or N9.25	5Y 3-4/1-2	10YR 2.5/1	7.5YR 5/6
	3	N1.75 5 or 10YR 2.5/1	N8.75	N1.75-2	5 or 10YR 2.5/1	10R 3/2
	4	N1.75	5Y 9/1	N1.75	5YR 2.5/1	5R 4-5/1
	5	N1.75 or 10YR 2.5/1	Vague, 5Y 9/2	N1.75	5 or 10YR 2.5/1	5R or 10RP 2.5 + 4-6/1
	6	N1.75	None	N1.75	N1.75	N1.75-2 + N4-7.75
	7	N1.75	None	10YR 9/2	N1.75	N1.75 + 4
	30°	4	5 or 10YR 2.5/1	5Y 9/1 or N9.25	5YR 2.5-3/1	5R 3-4 + 7/1
	5	5 or 10YR 2.5/1	5Y 9/1	N1.75	5YR 2.5/1	5R 2.5 + 5-7/1
	6	N1.75, 5 or 10YR 2.5/1	Vague	N1.75 or 10YR 9/1	5 or 10YR 2.5/1	10RP 2.5 + 4-6/1
	7	10YR 2.5/1	None	10YR 9/2	5YR 2.5/1	10RP 2.5 + 5/1
	33°	4	10YR 2.5/1	N9-9.5	N1.75	5 or 10R 3-4 + 5-8/1
	5	10YR 2.5/1	5Y 9/1	10YR 7-8/6	10YR 2.5/1	5R 2.5 + 5/1
	6	5 or 10YR 2.5/1	Vague	10YR 9/1-2	10YR 9/1-2	5R or 10RP 2.5 + 5-6/1
	7	None				
	30°	5	N1.75	Vague	N1.75	10RP 2.5 + 4-5/1
	6	10YR 2.5/1 N1.75	Vague	10YR 9/2 or N1.75	5YR 8/1	10RP 2.5 + 5/1
	7	10YR 2.5/1 + 6/6	5Y 9/1	10YR 9/1	10RP 3/2	10RP 3 + 9/1
	33°	5	N1.75	Vague	N1.75	5R or 10RP 2.5-5/1
	6	10YR 2.5/1	Vague	10YR 9/1-2	10YR 8-9/1	5R or 10RP 2.5 + 5-7/1
	7	None				
	30°	6	N1.75	Vague or none	N1.75	10RP 2.5 + 4-7/1 N1.75 + 4.75
	7	N1.75	Vague	N1.75 or 10YR 9/1	N1.75 or 5R 8/1	N1.75 + 4.5
	33°	6	N1.75	None	N1.75	N1.75 + 4.25-4.5
	7	None				
30°	1	5YR 2.5/1	10YR 9/1-2	5Y 4-5/2	5YR 2.5/1	10YR 7/6
	2	10YR 2.5/1	5Y 9/1	5Y 2.5/1	5 or 10YR 2.5/1	5YR 4/4
	3	5 or 10YR 2.5/1	5Y 9/1	N1.75	5YR 2.5/1	10RP 3 + 8/2
	4	10YR 2.5/1	5Y 9/1	N1.75	10RP 3 + 8/1	10RP 3 + 5-6/1
	5	10YR 2.5/1	Vague	5Y 2.5/1	10RP 3 + 8/1	10RP 2.5-3 + 5-7/1
	6	10YR 2.5/1	None	10YR 9/2	10RP 3/1	10RP 2.5 + 4-6/1
	7	None				
	20°	4	10YR 2.5/1	5Y 9/1	N1.75	5R 2.5 + 8/1
	5	N1.75	Very vague	N1.75	10RP 3 + 8/1	10RP 2.5 + 5/1
	6	N1.75	None	N1.75 or 3.25	10RP 2.5/1	N1.75 + 4.75 10RP 2.5 + 5/1
	7	N1.75	None	N3.25 - 5.25	N1.75	10RP 2.5 + 4/1
	25°	4	10YR 2.5/1	5Y 9/1	N1.75	10RP 2.5 + 5-7/1
	5	10YR 2.5/1	Very vague	N1.75	10RP 3/1	10RP 3 + 5/1
	6	N1.75	None	N1.75	10RP 2.5-1	10RP 2.5 + 4/1
	7	None				
	20°	5	10YR 2.5/1	Vague	5Y 9/1-2	10RP 2.5-3 + 5-7/1
	6	N1.75	None	N1.75	10RP 2.5/1	10RP 2.5 + 4/1
	7	N1.75	None	N1.75-3	10RP 2.5/1	10RP 2.5 + 4/1
	25°	5	10YR 2.5/1	Vague or 5Y 9/1	N1.75 or 10YR 9/4	10RP 3 + 6/1
	6	N1.75	None	N1.75 or 10YR 9/2	10RP 2.5-1	10RP 2.5 + 4-6/1
	7	N1.75	None	N1.75-3.5	10RP 2.5-1	10RP 2.5 + 4.5/1
	20°	6	10YR 2.5-1	None	N1.75 or 10YR 9/4	10RP 2.5 + 5/1
	7	N1.75	None	N3.5-4	10RP 2.5/1	10RP 2.5 + 4/1

See footnotes at end of table.

*acrea (Drury), reared under several temperature regimens*

Dorsum					General index <sup>5</sup>
Lateral striping	Lateral coloration <sup>3</sup>	Lateral verrucae (p) <sup>2</sup>	Lateral setae <sup>4</sup>	Venter	
5Y or 10YR 9/1, N9.25	5 or 10YR 8/6, 5YR 8/8	2.5Y 5/4	(6)	5Y 9/1, N9.25	
N9.25, 5Y 9/1	2.5 or 5Y 9/6	5Y 3/2, 5Y 9/2	5 or 10YR 2.5/1	N9.25, 5Y 9/1	
N9.25, 5Y 9/1	5Y 9/1 or 8.5/4	5Y 2.5/1	5YR 2.5/1	5Y 9/1, N9.25	
5Y 9/1	2.5 or 5Y 8/4	5Y 9/2 or 3/2	10YR 2.5/1	5R 7 or 8/1	
5Y 9/1	5Y 7 or 8/2	5Y or 10YR 9/1	5 or 10YR 2.5/1	5R or 10RP 4-7/1	
None, 5Y 9/1	None	10YR 9/1-4, N2	N1.75, 5-10YR 6/8	N4.75 10RP 5/1	6
None	None	10YR 9/1	5YR 6/8	N5.25	6
N9.25 or 5Y 9/1	5Y 8/2-4	5Y 9/2 or 4	10YR 2.5/1	5R 6-7/1	
5 or 10Y 9/1	5 or 2.5Y 7-8.5/2-4	2.5 or 5Y or 10YR 9/2	5 or 10YR 2.5/1	10RP 5-8/1	5
5Y 9/1	2.5 or 5Y 7-8/4-6	2.5 or 5Y 9/1-2	5 or 10YR 2.5/1	10RP 5-8/1	5
5Y 9/2	10YR 8/4-6	10YR 9/1-4	7.5YR 6/8	10RP 5-6/1	5-6
N9.25 5Y 9/1	5Y 8/4	5Y 3 or 9/2	10YR 2.5/1	5 or 10R 6-8/1	4
10 or 5Y 9/1-2	5Y 8/2	5Y 9/1	5 or 10YR 2.5/1	10RP or 5R 6-8/1	5
5 or 10Y 9/1-2	10YR 8/6	10YR 9/1	10RP or 5R 2.5/1	5Y or 10RP 6-8/1	4-5
5Y 9/2	2.5Y 8.5/4	10YR 9/1-2	10RP 2.5/1	5Y 8.5/2	4
N9.25	5Y 8/4	5Y 9/2	10YR 2.5/1	10RP 6-8/1	
5Y 9/2, N9.25	5Y 8.5/2	5Y 9/1	10YR 2.5 + 9/1	10RP or 5R 7-9/1	3
5Y 9/2	5Y 8.5/2	10YR 9/1	10YR 9/1	5Y 8.5/2	2
5Y 9/2	5Y 8.5/2	10YR 9/1	10RP or 5R 9/1	5Y 9/2	1
5Y 9/1 vague	5Y 8.5/1 or 2	5Y 9/1	5 or 10YR 2.5/1	5R 6-7/1	
5Y 9/1 vague	5Y 8/2 or 4	5Y 9/1	5R or 10RP 2.5/1	10RP 4-7/1	5
5Y 9/2 vague	10YR 8/4	10YR 9/1-2	10RP 2.5/1	N4.5	5-6
5Y 9/1 or vague	5Y 7/2	10YR 9/1	5 or 10YR 2.5/1	10RP 5-8/1	5
5Y 9/1-2	10YR 8/4	10YR 9/1-2	5YR 6/8	10RP or 5R 5-6/1	5
5Y 9/2	10YR 8/6	10YR 9/2	5R 2.5/1	5Y 7/1	5
5Y 9/1	5Y 8/2	10YR 9/1-2	10YR 2.5/1	10RP 6/1	
5Y 9/2	10YR 8/4	10YR 9/1	10RP 9/1	5Y 8.5/1	3-4
5Y 9/2	7.5YR 8/8	10YR 9/2	10RP 9/1	5Y 8.5/2	3
None 5Y 9/2	None 5Y 8.5/2	10YR 9/1	5YR or 7.5Y 6/8	N3.75-5 or 10RP 6/1	5-6
5Y 9/2	10YR 8/6	10YR 9/2	5 or 10YR 6/8	10RP 6/1	5-6
Vague 5 or 10Y 9/1	None 10YR 7/4	10YR 9/1-2	7.5YR 6/8	10RP 5/1 or N4.75	5
10Y 9/1	7.5YR 8/8	10YR 9/1	5YR 6/8	10RP 6/1	5
Vague 5Y 9/1	None	10YR 9/1	5YR 5/8 or N1.75	N4-4.75 10RP 5/1	6
5Y 9/2	10YR 8/6	10YR 9/1	10RP 5 + 9/1	5Y 8.5/1-4	4
5Y 9/1	5, 7.5 or 10YR 7-8/6	2.5 or 5Y 5/4	(6)	5Y 9/1	
5Y 9/1, N9.25	2.5 or 5Y 8-9/4-6	5Y 4/2	10YR 2.5/1	5Y 9/1, N9.25	
N8.75	2.5Y 8/6	5Y 3/1	5 or 10YR 2.5/1	N8.75	
5Y 9/1	2.5 or 5Y 8/6	2.5 or 5Y 9/1-2	5YR 2.5/1	5R 8-9/1	
5Y 9/1	2.5Y 8-8.5/6	2.5 or 5Y 8-9/2	5 or 10YR 2.5/1	5R or 10RP 5-6/1	
5 or 10Y 9/2	None	10YR 9/1-2	5YR 6/6	N4-8	6
5Y 9/2	10YR 7/4	10YR 9/2	7.5YR 6/6	N4.5	6
N9.25 or 5Y 9/1	5Y 8-8.5/6-8	5Y 9/6-8	5YR 2.5-3/1	5 or 10R 8-9/1	
5Y 9/1	10YR or 2.5Y 8/4	10YR 9/2-4	5 or 10YR 7-8/1	5R 6-8/1	
10Y 9/1	10YR 7-8/4-6	10YR 9/1-2	5 or 10YR 2.5/1	10RP 5-7/1	4-6
5Y 9/2	10YR 7/6	10YR 9/1	5YR 2.5/1	5Y 4/1	
N9-9.5	2.5Y 8.5/6	2.5Y 8/6	5YR 3/1	5 or 10R 8/1	
5Y 9/1	2.5 or 5Y 8/4	10YR 9/2	10YR 9/1	5R 6-9/1	
5 or 10Y 9/1-2	10YR 8/4	10YR 9/1-2	10YR 6-9/1	5Y 8.5/2	
5 or 10Y 9/1	2.5 or 5Y 8.5/2-4	5Y 9/2	5 or 10YR 2.5/1	10RP 5-7/1	4-6
5Y 9/1	10YR 7-8/4	10YR 9/1-2	5YR 8/1	10RP 6-9/1	3-5
5Y 9/1	10YR 8/4	10YR 9/1	10RP 3/2	5Y 8.5/2	3
5Y 9/1	2.5Y 8-9/4-6	2.5Y 9/2	10YR 7-9/1	10RP 5-7/1	
5Y 9/1-2	10YR 8/4	10YR 9/1-2	10YR 7-9/1	5Y 9/1	3
Vague or 5 or 10Y 9/1	10YR 7/4	10YR 9/1	5 or 10YR 2.5/1	N3.75-5 or 10RP 6/1	5-6
Vague or 5Y 9/1	10YR 7/4 or 8/6	10YR 9/1-2	5Y 8/1	N6.25 or 5Y 7/1	5
5Y 9/1	None	10YR 9/1-2	10YR 5/8	N4.25-6	6
10YR 9/1-2	10YR 7-8/6	5Y 4-5/2	5YR 2.5/1	10YR 9/1-2	
5Y or 10YR 9/1	5Y 8/4	5Y 3-5/2	5 or 10YR 2.5/1	5Y 9/1	
5Y 9/1	2.5Y 8/6	5Y 3/1-2	5YR 2.5/1	10YR 8-9/1	
5Y 9/1	5Y 8.5/4	10YR 9/1-2	10RP 3 + 8/1	10RP 6-8/1	
5Y 9/1	5Y 8/6	5Y 9/1-2	10RP 3 + 8/1	10RP 5-7/1	
5Y 9/2	10YR 7/6	10YR 9/2	7.5YR 6/6-10	10RP 5-6/1	4-5
5Y 9/1	5Y 8.5/2-4	5Y 9/2	5R 2.5 + 8/1	5R 7-8/1	4
5Y 9/1	5Y 8-8.5/2-4	5Y 9/1-2	10RP 3 + 8/1	10RP 5-7/1	5
Vague 5Y 9/1	None	10YR 9/2	10YR 6/8-10	10RP 3-5/1	5-6
Vague	None	10YR 9/4	10YR 6/10	10RP 4/1	6
5Y 9/1	5Y 8.5/2-4	5Y 9/2	10RP 3 + 8/1	10RP 7-8/1	
5Y 9/1-2	5Y 8-8.5/4	5Y 9/1-2	10RP 3 + 8/1	10RP 5-6/1	4
5Y 9/2	10YR 7/6	10YR 9/2	7.5YR 6-7/8	10RP 4-6/1	5-6
5Y 9/1-2	2.5 or 5Y 8.5/4	5Y 9/1-2	10RP 3 + 8/1	10RP 5-8/1	4-5
5Y 9/2	Vague	10YR 9/2	7.5YR 5-6/4-8	10RP 4-5/1	5-6
5Y 9/2	Vague	10YR 9/4	7.5YR 5/8	10RP 4/1	6
5Y 9/1	5Y 8-8.5/2-6	5Y 9/2	10RP 3 + 8/1	10RP 7-8/1	
5Y 9/1-2	5Y 8.5/4	10YR 9/1-2	7.5YR 6/6 or 10RP 3 + 8/1	10RP 4-7/1	4-5
5Y 9/2	10YR 7/6	10YR 9/2-4	7.5YR 5/8	10RP 4-5/1	6
5Y 9/2	10YR 7/6	10YR 9/2	7.5YR 6/6	10RP 5-6/1	4-5

TABLE 1.--Coloration of saltmarsh caterpillars, *Estigmene*

Base or test temperature	Larval instar	Head capsule	Dorsum			
			Middorsal line	Dorsal verruca	Dorsal setae	Laterodorsal stripe
33°	25° 6	10YR 2.5-/1	None	10YR 8/4 or 9/2	10RP 3 + 8/1	10RP 2.5 + 5/1
	7	10YR 2.5-/1	None	10YR 9/2-4	10RP 3 + 8/1	10RP 2.5 + 4-7/1
	1	2.5-10YR 2.5/1	10YR 9/1-2	5Y 4/2	5 or 10YR 2.5/1	10YR 7/6
	2	10YR 3/2 + 6/2-4	10YR 9/1	5Y 3-5/1-2	5 or 10YR 2.5/1	7.5R 3-4/2-4
	3	10YR 2.5/1 + 6-8/4	10YR 9/1	5Y 2.5/1	10YR 3/2	5R 4 + 7/2
	4	10YR 2.5/1 + 6-8/4	5Y 9/1	10YR 7-9/2-8	10RP 3 + 8/2	10RP 3-4 + 7/1-2
	5	10YR 2.5/1 + 6-7/4	5Y 9/1	10YR 9/2-4	10RP 3 + 8/1-2	10RP 3 + 7-8/2
	6	10YR 2.5/1 + 5-7/4-8	Vague	10YR 9/2 or 4	10RP 3 + 8/1	10RP 3 + 7-8/1
	7	10YR 2.5/1 + 6/6	Vague	10YR 9/2	10RP 8/1	10RP 4 + 8/2
	20° 4	10YR 2.5/1 + 7/4	5Y 9/1	10YR 7-8/4-6	10RP 3 + 8/1	10RP 3-4 + 7-8/1-2
33°	5	10YR 2.5/1	Vague or 5Y 9/1	10YR 9/2	10RP 3 + 8/1	10RP 2.5 + 6-8/1
	6	10YR 2.5-/1 or N1.75	None	10YR 9/2	10RP 2.5/1	10RP 2.5 + 4-5/1
	7	N1.75	None	N1.75	10RP 2.5-/1	10RP 2.5 + 4/1
	25° 4	10YR 2.5/1 + 6.8/2-4	5Y 9/1	5Y 2.5/1	10RP 3 + 8/1	10RP 3-4 + 6-8/1
	5	10YR 2.5/1	Very vague	N1.75 or 10YR 9/2	10RP 3 + 8/1	10RP 2.5-3 + 5/1
	6	N1.75	None	N1.75-3.5	10RP 2.5/1	10RP 2.5 + 4/1
	7	None				
	30° 4	10YR 2.5/1 + 6-8/2-4	5Y 9/1	10YR 8/4	10RP 2.5 + 8/1	10RP 3 + 7/1-2
	5	10YR 2.5/1	5Y 9/1-2	10YR 9/2-4	10RP 2.5 + 9/1	10RP 2.5-3 + 7-9/1
	6	10YR 2.5/1	Vague	10YR 9/2-4	10RP 3 + 7-8/1	10RP 2.5 + 5-6/1
33°	7	None				
	20° 5	10YR 2.5/1 + 6-7/4-8	5Y 9/1	10YR 9/2-4	10RP 3 + 8/1	10RP 2.5-4/6-9
	6	N1.75	None	10YR 9/2-4	10RP 2.5/1	N1.75 + 4.25
	7	None				
	25° 5	10YR 2.5/1 + 5-8/4-6	5Y 9/1-2	10YR 9/1-2	10RP 3 + 8/1	10RP 3-4 + 7-8/1
	6	N1.75	None	10YR 9/2	10RP 2.5/1	10RP 2.5 + 4/1
	7	None				
	30° 5	10YR 2.5/1 + 6-7/4-6	5Y 9/2	10YR 9/2	10RP 3 + 8-9/1	5R 2.5 + 6-7/1
	6	10YR 2.5/1 + 6-7/4-6	Vague	10YR 9/2-4	10RP 3 + 8/1	10RP 2.5 + 5-7/1
	7	None				
33°	20° 6	10YR 2.5/1 + 5-6/4-6	Vague	10YR 9/2	10RP 3 + 6-9/1	10RP 2.5 + 6-8/1
	7	None				
	25° 6	10YR 2.5/1	Vague	10YR 9/2-4	10RP 3 + 8/1	10RP 2.5-3/5-7
	7	None				
	30° 6	10YR 2.5/1 + 6/6	Vague	10YR 9/1-2	10RP 3 + 8/1	10RP 2.5-4 + 6-8/1
	7	None				

<sup>1</sup>Color coding from the Munsell Book of Color® (1):

N = neutral                      R = red  
 Y = yellow                      Rp = red-purple  
 YR = yellow-red

<sup>2</sup>Greek letter designation from Peterson (8).<sup>3</sup>In vicinity of lateral abdominal verrucae rho (8).<sup>4</sup>From verrucae eta and mu (8).

<sup>5</sup>1 = very pale                      4 = medium dark  
 2 = pale                              5 = dark  
 3 = medium pale                      6 = very dark

Absence of index number indicates all larvae were reared at the same base temperature.

<sup>6</sup>Inadequate size for evaluation.

acrea (Drury), reared under several temperature regimens--Continued

Dorsum					General index <sup>5</sup>
Lateral striping	Lateral coloration <sup>3</sup>	Lateral verruca <sup>2</sup>	Lateral setae <sup>4</sup>	Venter	
10RP 2.5 + 4/1	10YR 7/6	10YR 9/2	5YR 5/8	10RP 4-5/1	5
5Y 9/2	2.5Y 8.5/4	10YR 9/2	7.5YR 7/8	5Y 6-8.5/1	3-4
5Y 9/2	10YR 7/6	10YR 9/2	7.5YR 7/6	10RP 4-6/1	4
10YR 9/1-2	10YR 7-8/6	5Y 3-5/2	5 or 10YR 2.5/1	10YR 9/1-2	
10YR 9/1	10YR 8/6	10YR 9/1	5YR 3/2	10YR 9/1	
10YR 9/1	2.5Y 8/8	10YR 9/1-2	10YR 3/2	10YR 9/1	
5Y 9/1	2.5Y 8-8.5/8	10YR 9/1	10RP 8/2	5Y 9/1	3-4
5Y 9/1	2.5Y 8-8.5/4-8	10YR 9/2-4	10RP 3 + 8/1	5Y 8.5-9/1-2	3
5 or 10Y 9/2	10YR 8/6	10YR 9/1-4	10RP 3 + 8/1	5Y 8.5/2	3
5Y 9/1	2.5Y 8/6	10YR 9/2	10RP 3 + 8/1	5Y 8.5/4	2
5Y 9/1	5Y 8-8.5/2-6	10YR 8-9/1-4	10RP 3 + 8/1	5Y 9/1	2-3
5Y 9/1	2.5 or 5Y 8-8.5/2-4	5Y or 10YR 9/1	10RP 3 + 8/1	10RP 5-6/1	4
5Y 9/1-2	10YR 6-8/6	10YR 9/1-2	7.5YR 6-7/8	10RP 4-6/1	4-5
Vague	10YR 7/6	10YR 9/4	7.5YR 6/8	10RP 4/1	5
5Y 9/1	2.5Y 8/4-6	10YR 9/2	10RP 3 + 8/1	5Y 9/1	2-3
5 or 10Y 9/1-2	2.5Y 8-8.5/4-6	10YR 9/1	10RP 3 + 8/1	10RP 6-7/1	3-4
5Y 9/1-2	10YR 7-8/4-8	10YR 9/2-4	7.5YR 5-8/2-8	10RP 4/1	5-6
5Y 9/1	2.5Y 8/4-6	10YR 9/1	10RP 2.5 + 9/1	5Y 9/1	3
5Y 9/1-2	2.5Y 8/6	10YR 9/1-2	10RP 2.5-3 + 8/1	5Y 8.5/2	4
5Y 9/2	10YR 7-8/6	10YR 9/1-2	10RP 3 + 7-8/1	5Y 8.5/2	5
5Y 9/1	2.5Y 8-8.5/4-6	10YR 9/1	10YR 3 + 8/1	5 or 10Y 8.5-9/1	2-3
5Y 9/2	10YR 7-8/6	10YR 9/2	7.5YR 6-7/6-10	N4.5-5.5	5
5Y 9/1-2	2.5Y 8-8.5/2-6	10YR 9/1-2	10RP 3 + 8/1	5Y 8.5/1-2	1-2
5Y 9/2	10YR 7/6	10YR 9/2	7.5YR 6/10	10RP 4-6/1	5
5Y 9/2	2.5Y 8/4-6	10YR 9/1-2	10RP 3 + 9/1	5Y 8.5-9/2	2
5Y 9/2	10YR 7-8/6	10YR 9/2	10RP 3 + 8/1	5Y 8.5/2-4	3
5Y 9/2	10YR 7-8/6	10YR 9/2	10RP 3 + 8-9/1	5Y 8.5/2-4	2-3
5Y 9/1-2	10YR 8/4-6	10YR 9/2-4	10RP 3 + 8/1	5Y 8.5/2-4	3-4
5Y 9/2	10YR 8/4-6	10YR 9/1-2	10RP 3 + 8/1	5Y 8.5/2	2-3

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